Innovation and Access to Technologies for Sustainable Development: A Global Systems Perspective

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Abstract

This workshop report is a summary of themes discussed by five panels during a daylong workshop on "Innovation and Access to Technologies for Sustainable Development: A global Perspective" at Harvard University on April 24, 2014. The workshop brought together a diverse group of scholars to explore how the technological innovation needed for sustainable development can be promoted in ways that assure equitable access in current and future generations.

Three key themes that emerged from the workshop include: (1) The central role of power, politics and agency in analyzing technological innovation and sustainable development—an important aspect of this includes the articulation of the roles of actors and organizations within frameworks and models of innovation systems. (2) The importance of focusing both on supply-push and demand-pull mechanisms in innovation scholarship and innovation policy. (3) The need to focus more innovation scholarship around the goals of sustainable development.

Keywords: innovation system, technology, sustainable development, energy, health, agriculture, water, manufacturing

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Author Biographies

Alicia Harley is a doctoral candidate in Public Policy and a Giorgio Ruffolo Doctoral Research Fellow in the Sustainability Science Program at Harvard's Kennedy School of Government. She is interested innovation in agriculture systems and specifically how to govern innovation to improve the well-being of the most vulnerable farmers. She has two projects, which investigate the agriculture innovation system first comparatively across several States in India focusing specifically on the impact of subsidy design on the adoption of drip irrigation, and second within a single State (Bihar) where she works within a single village to understand the mechanisms of agriculture technology adoption and the impacts of state and central government policies to support agriculture development on small and marginal farmers. Using a structural systems model of the innovation system, she aims to expand the literature in innovation studies to include a greater focus on innovation in the context of power asymmetries and inequality. Alicia leads the food and agriculture systems working group as part of a collaborative project with the Initiative on Innovation and Access to Technologies for Sustainable Development led by Professor William Clark.

Sharmila L. Murthy is an Assistant Professor at Suffolk University Law School. She is also a Visiting Scholar with the Sustainability Science Program, Mossavar-Rahmani Center for Business and Government, and an Associate Fellow of the Human Rights to Water and Sanitation Program, Carr Center for Human Rights Policy, both at the Harvard Kennedy School of Government.

Laura Diaz Anadon is assistant professor of Public Policy at the Harvard Kennedy School (HKS), and associate director of the Science, Technology, and Public Policy program and co-faculty chair of the Energy Technology Innovation Policy research group, both at the Belfer Center for Science and International Affairs at HKS. Her research focuses on energy- and environment-oriented technological progress and seeks to: identify and quantify the diverse benefits that derive from it; map the complex factors (including institutions) that contribute to it; and create tools for policymakers to manage the systemic uncertainties that accompany it. She also studies the coupling between water, energy and food systems and its policy implications. Laura has worked on policy projects for various organizations (e.g., Climate Strategies on a World Bank project and the International Energy Agency). Her work has been published in journals including *Environmental Science & Technology*, *Energy Policy*, *Issues in Science &*

Technology, and Energy Economics, and she is working on finalizing Cambridge University Press book on "Transforming U.S. Energy Innovation". In addition to her work on energy innovation, systems analysis, and the water-energy-food nexus, Laura has published in chemical engineering and nuclear magnetic resonance journals, carried out process engineering research projects at DuPont and Bayer Pharmaceuticals and Johnson Matthey Catalysts, and worked as a financial consultant for banks on credit risk models for financing technology projects. Laura holds a Ph.D. in Chemical Engineering from the Magnetic Resonance and Catalysis Group at the University of Cambridge (UK), a Master in Public Policy from the Harvard Kennedy School, and a Master in Chemical Engineering from the University of Manchester (UK). She has also studied and worked on research at the University of Stuttgart (Germany).

Gabriel Chan is a Public Policy Ph.D. student and a Doctoral Research Fellow in the the Energy Technology Innovation Policy group, the Harvard Environmental Economics Program, and a former fellow of the Sustainability Science Program, at the Harvard Kennedy School of Government. His research focuses on innovation economics and policy in the energy sector using quantitative social science methodology. His interests lie in the interaction of government policy with radical technical change as well as in developing and applying cutting-edge statistical methodology to empirical questions in innovation economics, such as the estimation of technological spillovers from public R&D. Gabriel is a recipient of the Belfer Center Science, Technology, and Public Policy Fellowship (2012-2014), the Giorgio Ruffolo Sustainability Science Fellowship (2011-2012), the Vicki Norberg Bohm Fellowship (2010), and a graduate of the Harvard Graduate Consortium on Energy and the Environment (2012). Prior to coming to Harvard, Gabriel graduated from the Massachusetts Institute of Technology in 2009 where he received Bachelor of Science degrees in Earth, Atmospheric, and Planetary Science, and Political Science. In 2007 and 2009, Gabriel worked at the U.S. Department of Energy where he worked in the Climate Change Technology Program (CCTP), an interagency group tasked with prioritizing the federal government's investments and policies for mitigating climate change through accelerated technology innovation and deployment.

Kira Matus is an Assistant Professor in Public Policy and Management in the Department of Government of the London School of Economics. She is the Project Co-Director of the "Innovation and Access to Technologies for Sustainable Development" project in the Sustainability Science Program (SSP), and a SSP Visiting Fellow from 2012-present. Prior to joining the LSE in 2010, Dr. Matus was a Senior Policy Analyst at the Yale Center for Green Chemistry and Green Engineering. Dr. Matus received her PhD in Public Policy from Harvard University in 2009, where she was a doctoral fellow in sustainability science in the Sustainability Science Program from 2007 to 2009. From 2007-2009, she was a recipient the U.S. Environmental Protection Agency's (EPA) Science to Achieve Results (STAR) Graduate Fellowship. Dr. Matus also has an SM in Technology and Policy from MIT, and an ScB in Chemistry from Brown University.

Suerie Moon, MPA, PhD is Research Director and Co-Chair of the Forum on Global Governance for Health at the Harvard Global Health Institute. She is also a Lecturer in the Department of Global Health and Population at the Harvard School of Public Health, where she teaches a course on global governance and health. She also co-directs the Project on Innovation and Access to Technologies for Sustainable Development, Sustainability Science Program, at the Harvard Kennedy School of Government. Her work focuses on global governance, the political economy of global health (with a focus on innovation, access to medicines, intellectual property and equity), the evolution of international regimes, and innovative policies for addressing global problems. Prior to coming to Harvard, she worked for the Médecins Sans Frontières/Doctors Without Borders (MSF) international Campaign for Access to Essential Medicines, where she

focused on intellectual property policies, ensuring equitable pricing of medicines, and research and development into neglected diseases. She has also consulted for a number of international non-governmental organizations, think tanks, and intergovernmental organizations. Dr. Moon is a member of the editorial board of PLoS Medicine, Board of Directors of MSF-USA, the Drugs for Neglected Diseases Initiative-North America, the expert Proposal Review Committee of UNITAID, the Global Advisory Committee of the WHO project on local production for access to medical products, and the Chatham House Global Health Working Group on Financing. Her work has appeared in the New England Journal of Medicine, PLoS Medicine, Health and Human Rights, Globalization and Health, Global Health Governance, The Scientist, and other publications. She is the author (with Wolfgang Hein) most recently of the book: Informal Norms in Global Governance: Human Rights, Intellectual Property and Access to Medicines (Ashgate 2013). She received a BA in History from Yale University, an MPA from the Woodrow Wilson School of Public and International Affairs at Princeton University, and a PhD in Public Policy from the Harvard Kennedy School of Government.

Vanessa Timmer is co-founder and Director of the One Earth Initiative. From 2006-2008, Vanessa was Project Manager (External Relations) at Metro Vancouver (formerly Greater Vancouver Regional District – GVRD) as part of the Sustainable Region Initiative which brings together private sector, municipal governments, civil society and other partners to stimulate ideas and action around sustainability. Vanessa holds a Ph.D. in Resource Management and Environmental Studies from the University of British Columbia. Her dissertation focused on organizational structure and strategy of Friends of the Earth International and Greenpeace, and on their ability to adapt to change. From 2002 until 2003, Vanessa was a Fulbright Research Fellow at the Kennedy School of Government at Harvard University as part of the Initiative on Science and Technology for Sustainability. She holds a Bachelor of Arts (Honours) in Sociology from Queen's University and a M.Sc. in Environmental Change and Management from the University of Oxford.

William Clark is the Harvey Brooks Professor of International Science, Public Policy and Human Development at Harvard University's John F. Kennedy School of Government. His research focuses on sustainability science: understanding the interactions of human and environmental systems with a view toward advancing the goals of sustainable development. He is particularly interested in how institutional arrangements affect the linkage between knowledge and action in the sustainability arena. At Harvard, he currently co-directs the Sustainability Science Program. He is co-author of *Adaptive environmental assessment and management* (Wiley, 1978), *Redesigning rural development* (Hopkins, 1982), and *The global health system: Institutions in a time of transition* (Harvard, 2010); editor of the *Carbon dioxide review* (Oxford, 1982); coeditor of *Sustainable development of the biosphere* (Cambridge, 1986), *The earth transformed by human action* (Cambridge, 1990), *Learning to manage global environmental risks* (MIT, 2001), and *Global Environmental Assessments* (MIT, 2006); and co-chaired the US National Research Council's study *Our Common Journey: A Transition Toward Sustainability* (NAP, 1999). He serves on the editorial board of the *Proceedings of the National Academy of Science*. Clark is a member of the National Academy of Sciences and a Fellow of the American Association for the Advancement of Science. He is a recipient of the MacArthur Prize, the Humboldt Prize, the Kennedy School's Carballo Award for excellence in teaching, and the Harvard College Phi Beta Kappa Prize for Excellence in Teaching.

Sustainability Science Program

The Sustainability Science Program at Harvard University harnesses the University's strengths to promote the design of institutions, policies, and practices that support sustainable development. The Program addresses the challenge of sustainable development by:

- advancing scientific understanding of human-environment systems;
- improving linkages between research and policy communities; and
- building capacity for linking knowledge with action to promote sustainability.

The Program supports major initiatives in policy-relevant research, faculty research, training of students and fellows, teaching, and outreach. See http://www.hks.harvard.edu/centers/mrcbg/programs/sustsci.

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Innovation and Access to Technologies for Sustainable Development: A Global Systems Perspective

Report of a Workshop held at the Weatherhead Center for International Affairs, Harvard University, April 24, 2014

Report Written by:

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Date: August 21, 2014

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Introduction

This workshop report is a summary of themes discussed by five panels during a daylong workshop on "Innovation and Access to Technologies for Sustainable Development: A Global Perspective" at Harvard University on April 24, 2014. The workshop was convened by the Sustainability Science Program (in cooperation with the Science Technology and Public Policy Program) at Harvard Kennedy School of Government and sponsored by the Weatherhead Center for International Affairs.[1]

This one-day workshop brought together a diverse group of scholars from many countries and organizations (see Appendix A at end of report) to explore how the technological innovation needed for sustainable development can be promoted in ways that assure equitable access in current and future generations. The workshop also aimed to catalyze and identify new research in this area.

Sustainable development has been articulated as a shared global objective, and the problems that must be addressed to realize sustainable development are increasingly cross-border in nature. Key examples include global climate change, the transfer of pathogens and toxic substances, unhealthy lifestyles transcending borders, and volatility in global food commodity markets. Achieving the goals of sustainable development will of course require political leadership. But also needed is a significant and sustained increase in relevant technological as well as institutional innovations. While the literature has focused on technology, sectoral, national, or sub-national innovation systems, taking a global systems perspective on the innovation process provides important insights for several key reasons. First, the increasingly global movement of ideas, goods, services, and people means that the costs of investments into innovation may be geographically (and in some cases, temporally) separated from the benefits, suggesting that international institutions are required to overcome these externalities and ensure sufficient investment in innovation to meet sustainable development goals. Second, transnational non-state actors, such as private multinational firms, global civil society networks, and voluntary regulatory systems are playing crucial roles in innovation for sustainable development that may allow for learning across technologies. Third, the rapid global flow of information and knowledge highlights the need to build on the concept of national innovation systems, as the factors that shape innovation operate at increasingly dispersed scales. And fourth, meeting the needs of a global population, 84% of which lives in low- and middle-income countries, is likely to require institutional arrangements for promoting needed innovations that differ significantly from those established nationally in the industrialized countries. The institutions undergirding innovation in technologies for sustainable development, however, have sometimes been slow to evolve, such that the global innovation system remains less than the sum of its (national or technological) parts.

The workshop was focused around four questions (Appendix B includes the agenda for the day):

[1] Workshop web page <http://conferences.wcfia.harvard.edu/technologies_sustainable_development>. We would like to give a special acknowledgement to Marina Ivanova, who provided us with critical organizational and logistical support on behalf of the WCFIA.

1. How have innovation systems evolved beyond national boundaries to the global (or transnational) level? How has such evolution varied by sector? What are the implications for scholarly research, policy, and practice?
2. What processes and stages need to be included in useful frameworks for understanding or diagnosing innovation systems?
3. What are the methodological approaches that allow for generalizable understandings of innovation systems for sustainable development across cases?
4. What should transnational actors and institutions do to strengthen the innovation system for sustainable development at a transnational level?

These questions emerged from an ongoing interdisciplinary research project on "Innovation and Access to Technologies for Sustainable Development" that the workshop conveners have been conducting since the Fall of 2011. The project has involved over 30 scholars investigating innovation for sustainable development around the world and across five sectors of need: agriculture, health, energy, manufacturing, and water. The goal has been to move discussion of how to promote innovation with access beyond its disciplinary, sectoral, and national silos, across which the sharing of lessons about factors responsible for success and failure has often been ad hoc and limited. As background for the workshop, the conveners distributed a working paper that has resulted from this research to conference participants.[2] They also assembled a series of 15 relevant papers nominated by participants. These are listed in Appendix C.

We are grateful to all of the participants for their contributions to the workshop and as well as their insightful feedback on the working paper sent out in advance. This feedback has been invaluable to our own work and thinking.

This report summarizes the main themes in each panel from the workshop.

[2] Diaz Anadon, Laura, Kira Matus, Suerie Moon, Gabriel Chan, Alicia Harley, Sharmila Murthy, Vanessa Timmer, Ahmed Abdel Latif, Kathleen Araujo, Kayje Booker, Hyundo Choi, Kristian Dubrawski, Lonia Friedlander, Christina Ingersoll, Erin Kempster, Laura Pereira, Jennifer Stephens, Lee Vinsel, and William C. Clark. 2014. *Innovation and Access to Technologies for Sustainable Development: Diagnosing Weaknesses and Identifying Interventions in the Transnational Arena.* Sustainability Science Program Working Paper 2014-01. Sustainability Science Program and Belfer Center for Science and International Affairs, Kennedy School of Government, Harvard University, Cambridge, MA. http://www.hks.harvard.edu/centers/mrcbg/programs/sustsci/documents/papers/2014-01.

Panel 1. How have innovation systems evolved beyond national boundaries to the global (or transnational) level? How has such evolution varied by sector? What are the implications for scholarly research, policy, and practice?

The first panel set the stage for the day, exploring the broad question of the extent to which innovation systems increasingly cross borders, and whether and what difference this may make for research, policy, and practice. While recognizing that technological innovation (broadly defined to span from invention to dissemination to technology retirement) has operated across borders for over two millennia and that innovation systems are by nature open, the participants debated the extent to which globalization has intensified, expanded, and diversified such cross-border interactions.

The panelists offered concrete examples of parts of the global innovation system in two of the sectors where such institutions seem most advanced—agriculture and health. In agriculture, the involvement of the Rockefeller Foundation in supporting the development of improved seeds in the 1950s-60s led to the Green Revolution that took place in Asia and set the stage for the creation of the Consultative Group for International Agricultural Research (CGIAR). The CGIAR initially struggled with transferring agricultural technologies developed by scientists from one context to another, assuming that such technologies were more "portable" than was the case. Quickly however, a working model emerged in which basic researchers working internationally could partner with local plant breeders who could adapt technologies according to their knowledge of critical contextual factors (e.g., rainfall, soil, climate). The CGIAR achieved important successes but depended on public investment in agricultural R&D, much of it coming from development aid; thus when donor interest in agriculture waned in the 1980s, the system declined. Today, there seems to be renewed interest in agriculture and its role in sustainable development, but the landscape looks dramatically different from that of the publicly-funded CGIAR days. Rather, many different types of actors now shape technological innovation in agriculture, from large private corporations such as Nestle or McKinsey to large international NGOs like Oxfam, from major public donors such as the UK Department for International Development to new private donors such as the Gates Foundation, from inventive small-scale farmers to academic networks that can foster the cross-border spread of local knowledge, as well as the myriad public-private arrangements that tie these actors together. Moreover, despite the renewed interest in agriculture at the transnational level, the panelists agreed there remains significant need for increased funding, especially into technologies that benefit small and marginal farmers.

The panelists also observed similar trends in the health sector. The past decade witnessed a proliferation of actors and initiatives working to improve innovation and access to health technologies in developing countries, following a normative shift regarding the importance of equitable access to health technologies in the wake of the HIV/AIDS pandemic and investment of billions of dollars into health by the Gates Foundation. As in agriculture, actors span the range from public to private to not-for-profit, small-scale to global, and focus on both the invention or adaptation of health technologies (such as the public-private product development partnerships focusing on disease predominantly affecting the poorest populations) and delivery (such as the Global Fund to Fight AIDS, TB and Malaria, or the GAVI Alliance, which funds the

large scale purchase and delivery of drugs and vaccines in developing countries). Most of the new actors and networks operate transnationally but are not part of the formal UN system. Despite significant achievements, however, the system overall rests on fragile foundations and may be as susceptible as agriculture once was to the shifting preferences of donors.

The discussion following the panel presentation highlighted the normative shifts, the number and diversity of actors, and the density of cross-border networks illustrated in the agriculture and health sectors. Participants noted a number of other developments that underscored the relevance of taking a global or transnational perspective on innovation systems. First, the knowledge stock has grown exponentially and is also increasingly accessible across borders, with the potential for many positive spillovers. Second, negative externalities such as the impacts of climate change are also having an impact on a global scale. Both positive and negative externalities may lead to a greater convergence of disparate interests (or conversely, increased conflict) and strengthen the rationale for collective transnational action. Third, manufacturing is increasingly globalized with extended production chains that can have tremendous positive or negative implications for sustainable development. These implications often depend on the policies, certification systems, and guidelines developed by and among firms themselves (such as shrimp production or the sale of consumer goods such as soap or mobile phones).

Participants discussed how in some cases, market and normative incentives may be adequate for certain firms or industries to meet sustainable development needs—illustrated by firms taking 'bottom of the pyramid' approaches and incorporating sustainability considerations into their daily operations. On the other hand, there remain situations in which existing incentives and norms are inadequate to meet basic needs, such as research into neglected crops or diseases, access to sanitation, or products that are simply unaffordable for potential end-users. Relatedly, global trade has increased the interconnection between markets and the global trade rules that have been negotiated to govern such trade (e.g., intellectual property rights and foreign investment rules). Global financial flows have also increased—particularly in the direction of developing countries. Furthermore, norms have shifted considerably regarding both the environment and shared transnational responsibility for meeting certain basic human needs, as illustrated in the Millennium Development Goals and potentially also in the post-2015 Sustainable Development Agenda. Such norms have shifted expectations regarding the behaviors and policies of firms, governments, and other actors. Finally, governments of countries that had not previously been considered major sources of innovation, perhaps most notably China, are exerting growing and important influence on the global system.

These observations underscore the increasingly dense set of interactions that shape the innovation process operating across borders. Moreover, they highlight the need to consider what transnational norms, rules, and expectations are required to better govern such an emerging system. Considering that vigorous debate remains on issues such as the appropriate role of private versus public actors and suitable intellectual property rules within national innovation systems, these questions are likely to be even more complex and confounding when moving into the global arena and when looking across sectors.

Panel 2. What processes and stages need to be included in useful frameworks for understanding or diagnosing innovation systems?

The second panel discussed existing efforts to develop innovation frameworks for understanding and diagnosing barriers. The panel abstracted lessons about important components of innovation systems in theory and practice. In the panel, the speakers described how an innovation framework can be used to inform public policy through a diagnosis of bottlenecks in the system and to offer insights into leverage points to overcome weaknesses.

The panelists discussed (1) a conceptual framework for energy assessment used in the Global Energy Assessment Report (2012); (2) the important components of any framework for understanding innovation, including actors and institutions; and (3) the Innovation and Access Project's approach to analyzing the innovation system.

The panelists discussed a conceptual framework developed for the Global Energy Assessment including the following linked components: non-linear stages of innovation processes and feedbacks, and stocks of knowledge, technology, resources, and actors and institutions. In highlighting the key features of the framework, the panel noted that this framework included both processes that enhance these stocks (e.g., knowledge generation or economies of scale) and processes that reduce these stocks (e.g., knowledge depreciation or dis-economies of scale). Experience designing this conceptual framework led to several important lessons: First, panelists highlighted the importance of a systems perspective in innovation studies that includes stages, processes, and feedback. The panelists claimed that too often policy solutions address only one part of the innovation system, without accounting for complex dynamics across the innovation system, missing important dynamics which lead to unexpected and often ineffectual outcomes (e.g., trying to incentivize investment in carbon capture and storage technology without a price on carbon). Second, processes that reduce stocks, such as technology retirement and obsolescence, were highlighted as critical to making the innovation system function more dynamically. On this point, panelists noted that policy in China tends to support the phase-out of obsolete technology more effectively than in the US or Europe. Third, the importance of demand-side perspectives in innovation studies was highlighted. The panel claimed that a lack of emphasis on demand-driven innovation has been a shortcoming in the scholarly literature in the energy sector and may also be a problem across other sectors. Fourth, knowledge depreciation, especially due to erratic public policy creating uncertain investment environments in all stages of the innovation process, was highlighted as a major barrier to innovation. More generally, this point called for a greater emphasis on developing and utilizing innovation frameworks to capture not only mechanisms that support innovation but also on mechanisms that impede innovation.

The panel also discussed the importance of better understanding the role of actors in the innovation system. It is through actors that the mechanisms underlying the dynamics of the innovation system are driven and changed. Thus, as we study stages and processes in the innovation system, it is critical to map those back to the actors and how they behave. Actors include individuals and organizations as diverse as utility companies, trade associations, universities and research centers, financial institutions, NGOs, and transnational actors. In addition, there are emerging actors in the innovation system that serve linking functions,

especially across borders, such as the US-China Clean Energy Research Center. There are additional transnational linkages through flows in human labor and the skills and resources that accompany international movements in human capital. The actors that perform these linking functions highlight the importance of understanding the bi-directional flows connecting national innovation systems and global innovation systems. This is especially true in the context of innovation and access where innovations ideally diffuse to populations of millions or even billions, and in this context demand-side perspectives become particularly important. The panel discussed the importance of transnational actors determining where points of leverage in the innovation system exist and how to best intervene.

In discussing the Innovation and Access Project's approach to the innovation system, the panel described potential reasons to develop an innovation system framework, ranging from the evaluation of performance along societal objectives to diagnosing weaknesses and identifying barriers. An innovation system framework can also be used to identify areas of opportunity for policymakers. The Innovation and Access Project participants noted that the intellectual process of developing an innovation framework was useful in creating a common language between various disciplines and sectoral expertise. The Project's model draws on several disciplines including complex systems and system dynamics, technology innovation systems, economics of innovation, and global governance literatures, in addition to a set of empirical case studies conducted by the project team and commissioned authors and the sectoral specific experience and expertise of the Project's team. The flows of the innovation system framework created as part of the Project include invention, selection, initial adoption, production, widespread use, adaptation, and retirement. These flows link different technology stocks (e.g., invention stock and feasible technology stock), and mechanisms link technology stocks as drivers of change. Some important questions highlighted the need for further refinement in the framework regarding how causal drivers should be captured within the framework; the importance of incorporating supply-push and demand-pull mechanisms; how the framework should be tailored to specific audiences (e.g., policy makers, scholars, donors); and the appropriate unit of analysis for the innovation system framework (e.g., individual technologies, actors, and organizations, or institutions).

The discussion following the panel presentations highlighted several key themes. Linking actors to innovation frameworks emerged as a particular issue of importance to conference participants. The discussion also highlighted the challenge of including issues of serendipity, uncertainty, and risk into a model of the innovation system. The many "languages" spoken both across disciplines and sectors within innovation studies was cited as a barrier to progress. The importance of bridging terminology gaps to build trans- and inter- disciplinary models of innovation was emphasized.

Participants raised the question of what role institutional structures play in innovation systems. Beginning with a rational choice approach to institutionalism, can we identify the incentives in the system particularly around the goals of sustainable development? In what ways are existing and proposed institutions insufficient for achieving the goals of sustainable development? What new institutions are required?

In addition, the discussion touched on several dynamics not sufficiently emphasized in existing

innovation system frameworks. One example was the existence of "safe spaces" and anti-selection mechanisms for protecting specific early stage technologies. The importance of "niches" for biological innovation was raised as an example, suggesting the importance of strategic niche management in innovation systems more broadly. This concept has also been addressed in the innovation literature on socio-technical niche protection and strategic niche management.

Finally, issues of power were raised as important to innovation systems and innovation scholarship. The challenges of adequately addressing issues of power in innovation scholarship were noted. One place where issues of power arise is in the creation of preferences, which are too often treated as exogenously given in our models. It was noted that due to the clinical nature of innovation diagrams, power is often not clearly visible even if it undergirds many of the mechanisms at play. A call for continued involvement of political science in innovation scholarship was made to further refine the treatment of power in the literature.

Panel 3. What are the methodological approaches that allow for generalizable understandings of innovation systems for sustainable development across cases?

The third panel discussed three separate efforts to bring together a group of scholars studying innovation from different sectors and disciplines with the intention of drawing more general conclusions about innovation systems. The panel was asked to specifically address methodological approaches that can be used to facilitate the development of coherent conclusions when participating scholars come from different backgrounds and/or study different areas. The three efforts described in the panel were the development of the book, *Accelerating Innovation in Energy: Insights from Multiple Sectors* (2011), a special issue of the journal *Research Policy* titled "The need for a new generation of policy instruments to respond to the Grand Challenges" (2012), and the Innovation and Access Project's framework for looking at innovation in the specific context of sustainable development.

The panelists highlighted their initial skepticism regarding their chosen methodological approach's ability to reach generalizable understandings that were novel, interesting, and important. The panelists also highlighted the high "startup cost" to their efforts that slowed progress at initial stages due to difficulty in communicating in a common language and with a shared set of assumptions and experiences. For example, two panelists highlighted that drawing conclusions about innovation in the energy sector by using lessons from other sectors was extremely challenging because of fundamental differences across those sectors (e.g., the demand structure to support energy R&D is not guaranteed, as it is for defense R&D). As another example, one panelist described the challenge of even defining "mission-oriented R&D," the focusing topic of their entire effort, in the early planning of their project. Doing so required grappling with the high degree of heterogeneity in innovation systems in different sectors. To overcome the "startup cost" challenge, one panelist highlighted their deliberate methodological decision to hold a series of three conferences where participating experts could build a common understanding. Perhaps unsurprisingly, developing a common language was found to be easier among a group of scholars from the same academic discipline. At the same time, however, it was conceded that a single-disciplinary background can lead to a narrowing of

understanding regarding mechanisms in the innovation system.

The three efforts that the panelists described each attempted to draw conclusions based on a set of specific case studies that may be applicable in other more general, sector-specific, or technology-specific contexts. All three panelists emphasized the utility of convening or commissioning people with deep expertise in an area to conduct the specific case studies in that area. Further, all three efforts utilized a workshop or seminar format to convene all of the individual case study authors as a step in generalizing findings. The approaches that the panelists described for generalizing findings varied in their study designs: from generalizable findings hashed out during a workshop with the participating case study authors to case studies matched based on shared characteristics and conclusions drawn from analysis of these matched case studies.

During the discussion, one additional specific methodological approach was raised. This approach was described as a labor and data-intensive "event study" methodology based on the Minnesota Innovation Research Program and studies of organizational change. The approach, which is an alternative to conducting a complex array of case studies, attempts to find whole sets of events that drive technological change and then cluster the events to uncover which precursor events were most important or absent. This approach also forms the basis of the analysis underlying the implementation of the innovation functions approach.

Participants drew a contrast between methodological approaches for understanding the innovation system that begin with a common theoretical grounding and language (roughly deductive reasoning), and approaches that build up from empirical observations (roughly inductive reasoning). Several participants suggested that inductive approaches were more difficult to implement. As a starting point, discussants suggested that deductive approaches could begin with propositions from science and technology studies or from the literature on national innovation systems. Another participant, however, warned that the current literature is "light" on framework development but "heavy" on case studies.

In addition to this more general discussion, participants also identified specific issues: (1) the need to capture specific national innovation system differences within a framework of the global innovation system; (2) framing analyses for different audiences which are often diffuse in the public sector, private sector, and academia; (3) the difficulty in assessing counterfactuals; (4) approaches for controlling for specific aspects of the innovation system, such as comparing different technologies within the same innovation system, comparing the experiences of the same technology in different innovation systems, or studying a single technology all the way through widespread use and retirement, with particular attention to dynamics; and (5) differences between an innovation system focused on meeting sustainable development goals and an innovation system oriented for other goals.

The participants also commented on several specific issues not directly related to methodological approaches. These included: (1) the history of U.S. shale gas development and the role of various public and private actors; (2) the utility of modeling the volatility in innovation system "stocks" over time and the ways in which these stocks are mobilized by actors and institutions; (3) the processes that government bureaucrats and leaders use to make "smarter" decisions and the importance of having strong champions; and (4) developing a

shared set of canonical innovation case studies to facilitate a common starting point for students of innovation policy.

Panel 4. What should transnational actors and institutions do to strengthen the global innovation system for sustainable development?

The fourth panel discussed the issues of what transnational actors can do and how institutions could evolve to strengthen the global innovation system for sustainable development. The panelists discussed the provision of global public goods—e.g., dissemination of information to promote additional invention, mitigation of global environmental problems, and addressing network externalities—as one of the important areas in which actors in the transnational arena may play important roles. The panelists drew on examples from health in order to highlight a number of success stories at the transnational level, which addressed perceived weaknesses in the innovation system.

The first example highlighted work by a coalition of actors including Oxfam, UNDP, and UNITAID that started in the mid-2000s to restrict the granting of secondary patents on pharmaceuticals in India and Brazil. This effort was part of a counter-harmonization movement that emerged in response to the 1995 Treaty-Related Aspects of Intellectual Property Rights (TRIPS) agreement, which mandated a gradual harmonization of national intellectual property rights regimes. This coalition of actors catalyzed legal amendments to raise the bar for awarding secondary patents—namely, additional conditions in India and another review body in Brazil. In spite of the success that the coalition had in changing national laws, the fraction of secondary patents that are rejected in India and Brazil has only increased by under 3% and 5%, respectively, calling into question the strategy's effectiveness. In particular, resource constraints have arisen as a major barrier to the implementation of the new laws.

The Pandemic Influenza Preparedness (PIP) Framework is a second example of existing transnational action from the health sector. Under this 2011 framework, the World Health Organization (WHO), its member states, industry, and other stakeholders implemented a global approach to pandemic influenza preparedness and response. This framework was triggered by the government of Indonesia, which conditioned its willingness to provide virus samples to WHO and others on arrangements to facilitate access to the vaccines that would subsequently be developed from such samples. A final area of growing attention in the health sector has been a push by the NGO community to develop an international treaty to fund R&D on health conditions affecting poor populations. This effort, however, has received only weak support or even opposition from some governments and firms.

The panel also discussed an example from the agriculture sector. The International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) came into force in 2004, over 10 years after the Convention on Biological Diversity laid out the principles of access to genetic resources and benefit sharing. This treaty, negotiated under the auspices of the Food and Agricultural Organization (FAO), created a multilaterally governed gene pool of more than 1 million accessions of plant genetic material, which constitutes a commons for biological materials with low transaction costs. It ensures access and addresses concerns about

information asymmetry and transaction costs since genetic plant material is made available free of cost for research and training purposes.

The Innovation and Access Project posited that transnational action is needed when transnational collaboration is more effective or efficient than national action alone or when there is a shortfall of resources at the national level. It presented a set of functions that transnational actors can perform: setting goals, priorities, and agendas; reducing transaction costs; reducing information asymmetries; internalizing transnational externalities; reducing social distance; building capacity; and reducing costs. It also articulated the set of resources that may be needed to perform the different functions: normative authority; convening power; information; expertise and skills; and finance. Some of these functions are closely interrelated. For example, reducing transaction costs will also reduce (net) costs, reducing information asymmetries may reduce risk, and reducing risk will often reduce (net) costs. Given that actors have varying resources and that different goals and technologies merit distinct interventions, the Project highlighted that a strengthened innovation system does not necessarily imply the construction of a global, centrally coordinated innovation system. Rather, it implies an analysis of the bottlenecks, resources needed, possible interventions, and suitable actors and institutions.

In addition to understanding the characteristics of the technologies and the bottlenecks that may arise in the innovation process, the characteristics of the actors and institutions that could intervene to clear such bottlenecks need to be evaluated. Indeed, from an analytic perspective, one could separate what type of intervention or activity ("function") is needed to increase innovation and access to a technology to address a particular sustainable development need, from the actor that is well-positioned to perform this intervention.

A recurring theme in the discussions was the role of multinational corporations as increasingly important actors in the system, given their resources and international reach. As one participant pointed out, while in the 1980s, 80% of North to South financial flows came in the form of government foreign aid, in 2014 about 75% of North to South financial flows came from foreign direct investment. The implication of this shift is that international corporations may have more leverage to create change, such as abolishing poor labor practices, than donors or intergovernmental organizations such as the International Labor Organization. And in agriculture it becomes very difficult to think about promoting innovation to meet food needs without the participation of corporations given that today, unlike thirty years ago, large segments of relevant expertise reside exclusively in the private sector. At the same time, trends will vary across different actors and industries. For example, some pharmaceutical firms either conduct no research or have decreased their investment into diseases that primarily affect developing countries, citing an unsustainable system of incentives to continue doing so.

Indeed, there may be issues that are unlikely to be addressed by markets alone. Transnational civil society organizations, for example, may be good at amplifying issues, monitoring, assessing, learning, and playing the role of boundary spanners in the innovation system—a role that multinational corporations may be less willing to play. And while philanthropic organizations such as the Gates Foundation are also playing growing roles in the transnational arena, there are questions about whether or not their actions are adequate substitutes for initiatives that

governments should undertake. Overall, participants stressed the importance of trying to understand the types of coalitions that arise as part of the polycentric system of governance that currently characterizes the global arena.

Along the theme of functions that may sometimes be needed at the transnational level, it may be important to explicitly consider a function of enabling learning, editing, and filtering of experiences or strategies. An important task for researchers may be to identify the type of past experiences that policy makers and analysts are using to design policies and interventions, and to point out when particular historical analogies may not work. Experience suggests, however, that the use of historical analogies can be difficult to dispel.

The wide range of activities that are taking place in the transnational arena highlight the need to better understand when transnational action is necessary; the roles that various actors (or coalitions of actors) could play; and what transnational institutions need to be strengthened, reformed or created to contribute to innovation for sustainable development.

Panel 5. Summary

During the final session of the workshop, key insights and conclusions were drawn from the prior sessions in "synthesis" panels.

Synthesis of Panel 1—Global dimensions of modern innovation systems
The first summary panel stressed the value of assessing what is new about the global innovation system, including the internationalization of research and development, while also exploring those elements of the innovation system that are adequately addressed within the coherent boundary of national innovation systems.

Further analysis of the role transnational actors are playing in bridging the national, regional, and international systems, and how they shape global priority setting, is critical for learning about the emerging global governance structure. For example, there are an increasing number of activities at the international level being driven by private actors including those with global integrated value chains such as Unilever.

Certain critical factors for the global innovation system, such as intellectual property rights, may be more important in sectors such as health and agriculture than in infrastructure sectors such as energy and water.

A few global trends merit further research including the impact of students traveling across the globe; the role of higher education as a means of global connectivity; changes and variation in access to finance; and the emergence and influence of evolving global environmental norms.

Synthesis of Panel 2—Analytic frameworks for diagnosing bottlenecks
In the European scholarship, specifically the transitions literature, there are two competing models of innovation: 1) a multi-level perspective that explores innovation across niches, regimes, and landscapes, and 2) an analysis that explores the innovation system as a whole, focusing on technologies or sectors. However, the scholarship in this area has largely not addressed sustainable development or more specifically, underserved populations.

Frameworks should allow for an analysis of systemic weaknesses and take into account the geography of change.

Critics of innovation systems theory predominately note the limitations of national innovation systems analysis. However, the focus of our analysis goes further and explores both international linkages and sustainable development. In this sense, the frameworks we seek to develop are more aligned with sectoral and technological innovation systems and the recent discussions on the geography of innovation systems.

Systems are by nature complex with many factors, components, and processes. In developing a framework, we can explore innovation systems in many different ways and reveal different things. We can analyze them in terms of their components—actors, institutions, networks, and technological infrastructures. Frameworks can reveal whether there is a dominant focus, for example on the supply side of innovation as compared to the demand side. We can also look at innovation stages and discuss how much detail we want to include in exploring the stages. An analytical framework can explore the processes of innovation: resource mobilization, entrepreneurial development, and overcoming resistance to change. The system can be analyzed in terms of the degree to which it is embedded and the degree of technological lock-in. In order to explore power dynamics and legitimacy formation, innovation systems are usefully explored from a historical perspective and through analysis based in political economy, sociology, and the social sciences. The innovation systems concept is shared by many disciplines and conceptualized differently across these disciplines, and there is value in fruitful debate among these viewpoints.

Synthesis of Panel 3—Methods for generalizing across cases / sectors

As the scholar Joseph Schumpeter noted, economic analysis needs history, theory, and statistics. The workshop focused on a historical analysis of case studies and industry sector studies. This has yielded deep knowledge as crystallized in the model presented in the background paper. There is a need for additional data and statistical analysis in order to explore key aspects of the innovation system such as the costs of technology transfer from one nation to another. One particular area in which more quantitative research is needed is the measurement of absorptive capacity. In their pioneering study of technology transfer of computer control of machine technology, Harvey Brooks and Maryellen Kelley highlighted the role of international technical conferences in which people learned from one another. This played a critical role in Japan. There is also value in exploring the role of private company sales representatives and engineering sales representatives in terms of stimulating what is needed in the market and of diffusing technology to their customers.

Synthesis of Panel 4—Priorities for transnational actors / institutions

There is a fundamental error in assuming that the variables and processes of national innovation systems are analogous to similar aspects at the transnational level. For example, each nation has a department of defense and a “strategic brain,” but there are no counterparts at the global level. In fact, there may have been greater central conceptual and institutional mechanisms at the global level in the post-war era than exist today. The characteristic feature of international law is fragmentation into sub-fields with few overarching concepts.

At the global scale there are no "central brains" that drive innovation such as the National Institute of Health and Department of Defense in the United States. Instead, the global innovation system can be better modeled as a polycentric governance structure. Thus, the extensive existing literature on polycentric governance can lead to important insights especially for ways forward to address barriers in the international innovation system. For example, there are public governance mechanisms, international law-making processes, and the development of international law such as sanctions. There is a system of corporate governance, government, and civil governance. The role that civil society actors play is increasingly linked and more coordinated, including through support from foundations. For example, the Ford Foundation provided a $50 million grant to human rights organizations in the South to enable them to connect at the transnational level.

Building on the polycentric governance literatures, there is a need within innovation studies to specify the functions in a manner that recognizes the polycentric nature of global governance, and in particular to explore the interface of different actors. The functions that are currently defined in most models are generic and do not reflect the specificities of the transnational arena. A global innovation system framework should go beyond the various mapping frameworks provided in the background paper in order to specify which transnational actors are being considered and what activities they are engaged in. Further exploration is warranted of the role of intermediaries such as the World Economic Forum, business and civil society leaders, and the Clinton Global Initiative. Different actors can be analyzed by their functions and resource capacities.

Conclusions

Overall, despite a diversity of views on technological innovation, methods, frameworks, the goals of sustainable development, and global governance, participants seemed to agree that further analysis and research drawing together these often disparate strands of scholarship is needed. With the post-2015 Sustainable Development Agenda just on the horizon, many questions remain unanswered regarding not only what such goals should be, but even more importantly, how they can be achieved. In particular, careful thinking and analysis is merited on what functions need to be performed in the transnational arena, what institutions are needed, and what various types of actors—from scholars to business, from civil society to governments—should do to advance progress towards realizing sustainable development.

Three key themes that emerged from the conference include:

1. The central role that power, politics, and agency should have in analyzing technological innovation and sustainable development. An important aspect of this includes the articulation of the roles of actors and organizations within frameworks and models of innovation systems.
2. The importance of focusing both on supply-push and demand-pull mechanisms in innovation scholarship and innovation policy.
3. The need to focus more innovation scholarship around the goals of sustainable development.

Once again, the organizers of the conference thank all participants for their participation and enthusiasm over the course of a stimulating day.

Appendix A: Workshop Participant List

Kathy Arujo, Harvard University, Kennedy School of Government
Carlos Correa, University of Buenos Aires, Faculty of Law
Edward Cunningham, Boston University
Kelly Sims Gallagher, Tufts University, Fletcher School of Law and Diplomacy
Arnulf Grubler, International Institute for Applied Systems Analysis
Peter Hall, Harvard University
Marko Hekkert, Utrecht University
Rebecca Henderson, Harvard University, Harvard Business School
Calestous Juma, Harvard University, Kennedy School of Government
Louis Lebel, Chiang Mai University
Joshua Lerner, Harvard University, Harvard Business School
Richard Lester, MIT
David Mowery, University of California Berkeley, Haas School of Business
Robert Paarlberg, Wellesley College
Varun Rai, University of Texas Austin
John Ruggie, Harvard University, Kennedy School of Government
Bhaven Sampat, Columbia University, Mailman School of Public Health
F. Michael Scherer, Harvard University, Kennedy School of Government
Bernhard Truffer, Swiss Federal Institute of Aquatic Science and Technology
Lee Vinsel, Stevens Institute of Technology
Paul Wilson, Columbia University, Mailman School of Public Health

Laura Diaz Anadon, Harvard University, Kennedy School of Government
Gabriel Chan, Harvard University, Kennedy School of Government
William C. Clark, Harvard University, Kennedy School of Government
Alicia Harley, Harvard University, Kennedy School of Government
Kira Matus, London School of Economics and Political Science
Suerie Moon, Harvard University, School of Public Health
Sharmila Murthy, Suffolk University, School of Law
Vanessa Timmer, OneEarth

Appendix B: Workshop Agenda

9:00 - 9:30 am - **Welcome and Introduction by** William Clark

9:30 - 11:00 am - **Panel 1**: ***How have innovation systems evolved beyond national boundaries to the global (or transnational) level? How has such evolution varied by sector? What are the implications for scholarly research, policy and practice?***

Moderator: Vanessa Timmer
Panelist 1: Paul Wilson
Panelist 2: Robert Paarlberg
Panelist 3: Alicia Harley
Synthesizer: Bernhard Truffer

11:00 am - 12:30 pm - **Panel 2**: ***What processes and states need to be included in useful frameworks for understanding or diagnosing global innovation systems?***

Moderator: Kira Matus
Panelist 1: Arnulf Grubler
Panelist 2: Varun Rai
Panelist 3: Gabe Chan
Synthesizer: Marko Hekkert

1:30pm - 3:00pm **– Panel 3:** ***What are the methodological approaches that allow for generalizable understandings of global innovation systems for sustainable development across cases?***

Moderator: Sharmila Murthy
Panelist 1: Rebecca Henderson
Panelist 2: David Mowery
Panelist 3: Laura Diaz Anadon
Synthesizer: Mike Scherer

3:15 - 4:45 pm - **Panel** 4: ***What should transnational actors and institutions do to strengthen the global innovation system for sustainable development?***

Moderator: Bill Clark
Panelist 1: Bhaven Sampat
Panelist 2: Carlos Correa
Panelist 3: Suerie Moon
Synthesizer: John Ruggie

5:00 - 5:30 pm - **Panel of Synthesizers**
Synthesizer 1: Bernhard Truffer
Synthesizer 2: Marko Hekkert
Synthesizer 3: Mike Scherer
Synthesizer 4: John Ruggie

5:30 - 5:45 pm - **Concluding Remarks by** Kira Matus

Appendix C: Background Materials Provided by Conference Participants

For working papers and manuscript drafts, please contact the author directly. All other materials are publicly available.

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